POWER

RECTIFIERS

MOTOROLA

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MAIN RECTIFIER PARAMETERS

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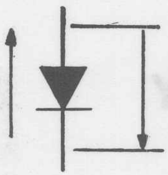
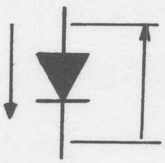
I_R  V_R *REVERSE VOLTAGE*

- *EFFICIENCY FACTORS*

I_F  V_F *FORWARD DROP VOLTAGE*

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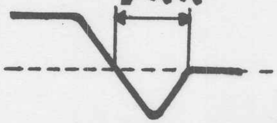
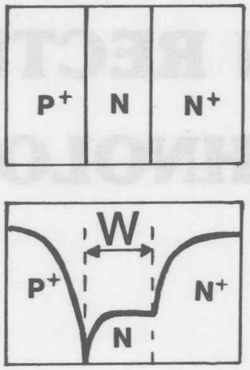


DIFFUSION PROFILE OPTIMISATION



Low recovery time ⟷ **Decrease Nzone width** W

Low forward voltage ⟷ **Decrease Nzone width and**

sharp fall of P+ concentratio

High reverse voltage ⟷ **Increase Nzone width**

THERE IS NO IDEAL RECTIFIER

The diffusion profile

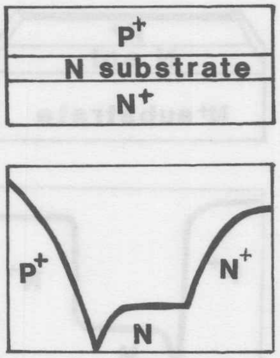
should be adapted

to application requirements

MAIN RECTIFIER TECHNOLOGIES

- FAST RECOVERY : double diffused
- ULTRAFAST : epitaxial diode
- SCHOTTKY : metal/silicon junction

DOUBLE DIFFUSED DIODE



DIFFUSION PROFILE NOT WELL CONTROLLED

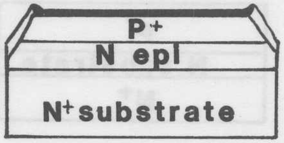
LARGE CENTRAL LAYER

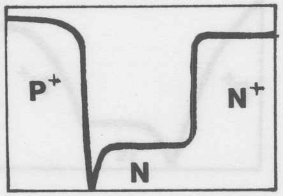
HIGH REVERSE VOLTAGE (1000v)

BUT HIGH FORWARD VOLTAGE (1.1v)

AND HIGH TRR (100nS)

EPITAXIAL DIODE





TIGHT PROFILE CONTROL

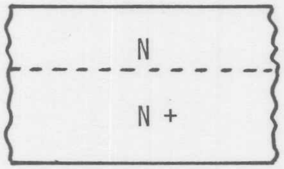
NARROW CENTRAL LAYER

LOW FORWARD VOLTAGE (0.8v)

AND LOW Trr (30nS)

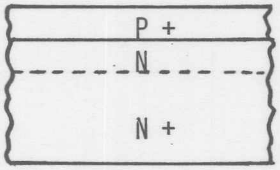
BUT LOW REVERSE VOLTAGE (200v)

THE ULTRAFAST TECHNOLOGY



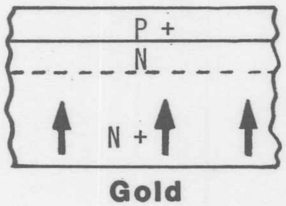
NARROW EPITAXIAL LAYER ON N + SUBSTRAT

⟶ **Reduce Resistivity**



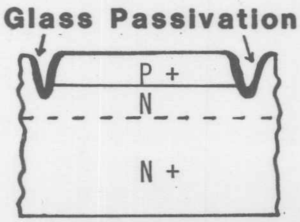
P + STEEP DIFFUSION

NARROW N LAYER ⟶ **Low VF**



GOLD DOPING

RECOMBINATION CENTRES ⟶ **Low Trr**



ETCHING AND PASSIVATION

GLASS PASSIVATED JUNCTION

⟶ **Increase Vr**

⟶ **Protection of P+/N junction**

THE SCHOTTKY

POWER RECTIFIER

I. JUNCTION STRUCTURE

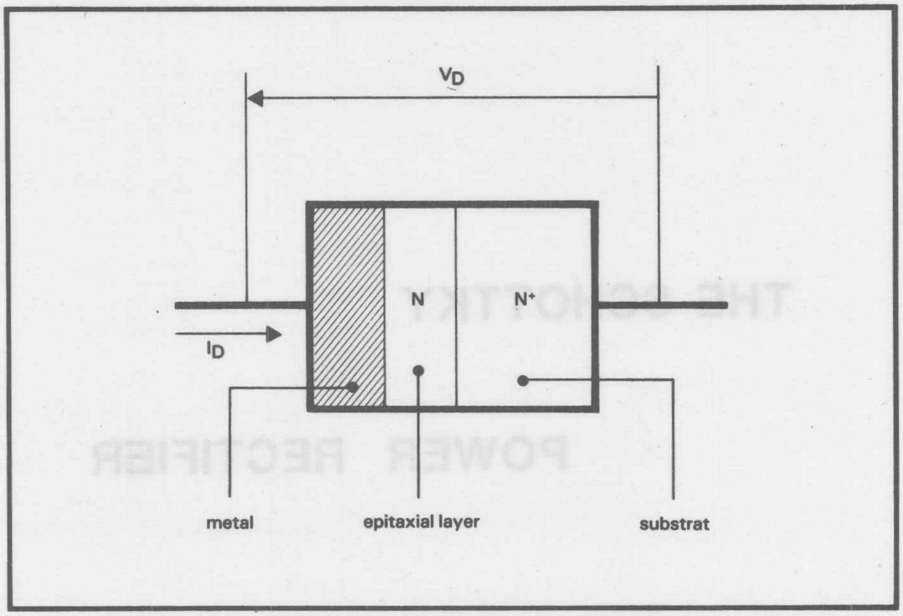


FIGURE 1

A schottky diode consists of a junction of semiconductor material which is epitaxially grown N type on a N^{+} substrate, and a metal layer which plays the role of a P^{+} region. In theory the metal – N interface can be considered as a typical $P^{+}N$ junction.

In such a structure of metal – N, the current which flows thru the diode is by majority carriers, while in the PN junction, conduction is by minorities carriers. The life of the majority carriers is such shorter than that of the minority carriers which is the most important advantage of this structure. Compared to a classical PN junction, the reverse recovery time of a schottky diode is pratically zero.

It is therefore the nature of the metal – N junction which assures the very low reverse recovery times. Contrarily the gold doped fast recovery diode's time are quite dependant on process quality and control. For the schottky diode, the reverse recovery time is negligible in principal, therefore it is not specified as a device parameter.

The actual structure used for MOTOROLA schottkys is shown below in cross section.

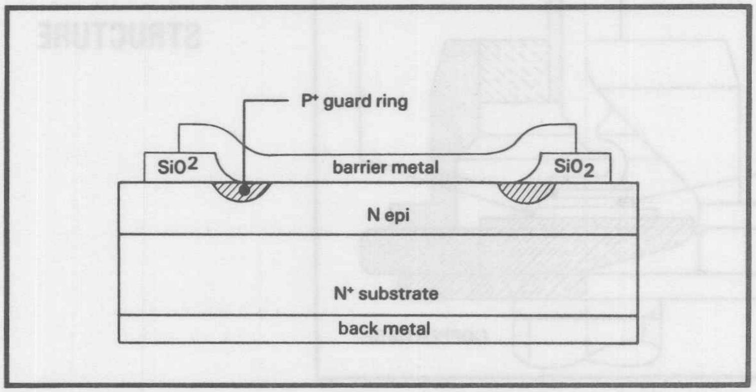
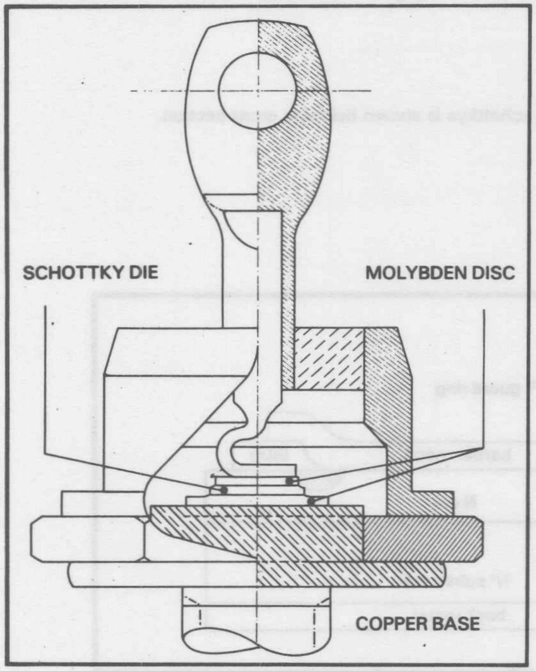


FIGURE 2

MOTOROLA schottky employ a special P^+ guard ring as shown in fig. 2. This guard ring is very effective in reducing field concentration edge effects between the metal – N junction which reduces reverse breakdown voltage. In reverse bias, the radius of curviture from the PN junction depletion is much larger then the schottky alone would have at the edge of the metal contact. Thus the field concentration is reduced and the breakdown voltage is increased by the PN guard ring. Electrically the PN junction is in parallel with the schottky junction and should also serve as a transient suppressor in applications of reverse bias. That is the PN junction avalanches before the "schottky" junction.

MOTOROLA SCHOTTKY RECTIFIERS



A PERFORMING STRUCTURE

A TOP LEVEL HIGH QUALITY PROCESS

- "ZERO DEFECT" WAFER SELECTION
- ION IMPLANTED P^+ ANNULAR RING
- TRIPLE LAYER FRONT GOLD METALLIZATION
- 100% DICE PROBED
- "SANDWICHES" ASSEMBLY WITH MOLYBDENUM DISCS
- TEMPERATURE STABILIZATION BAKE
- 100% ELECTRICAL AND VISUAL "SANDWICHES" TEST
- AFTER ASSEMBLY 100% TEMPERATURE STORAGE AND TEMPERATURE CYCLING PER MIL STD COND B
- 100% FINAL TEST WITH TEMPERATURE GUARANTEE
- CONTINUOUS LINE AUDIT AND RELIABILITY PROGRAM

II. FORWARD CHARACTERISTICS

In a metal – N diode the current density, J, of the junction can be expressed as:

$$J = Js \exp\left(\frac{qV}{KT} - 1\right)$$

II-1 $$J = Js \exp\left(\frac{qV}{KT}\right) \text{ when } V > 0.1 \text{ Volt}$$

where Js is the satured current density expressed as:

II-2 $$Js = RT^2 \exp\left(\frac{-q\,\varnothing B}{KT}\right)$$

where: R = Richardson constant
= 120 A/cm² × (°K)²

T = absolute temperature (°K)

K = Bolzman's constant
= 8.62×10^{-5} eV/°K

q = electron charge
= 1.6×10^{-19} coul.

ØB = barrier height (eV)

The **barrier height**, ØB, represents the energy barrier level for charge transfer at the metal – N interface. For a voltage applied in excess of this energy level, the junction will allow the flow of charge. Therefore the barrier height, ØB, is a very important parameter. ØB is dependent on the physical quality of the metal – N interface and the type of the metal used as indicated in Table I.

METAL	ØB (eV)
Pt	0.87
Mo	0.59 to 0.68
Ni Pt	0.65 to 0.75
Ni	0.60
Cr	0.55 to 0.65

Therefore it is the physical metal-Si interface which causes the principal difficulties in the industrial fabrication of a schottky diode. If it is not closely controlled, the variations in ØB can drastically change the most important forward and reverse characterizations.

Application example

a) Procedure for calculating the satured current density, Js, for chrome and nickel platinium metals.

$$Js = RT^2 \exp \frac{-q\, ØB}{KT}$$

where R = 120
KT/q = 26 mV (room temperature)

For the nickel platinum, ØB = 0.7 ev

$$Js = 120 \times (300)^2 \times \exp \frac{-q\, ØB}{KT}$$

$$= 1.08\ (10^7) \times 2.03\ (10^{-12})$$

$$= 2.19\ (10^{-5})\ A/cm^2$$

$$Js = 0.02\ mA/cm^2$$

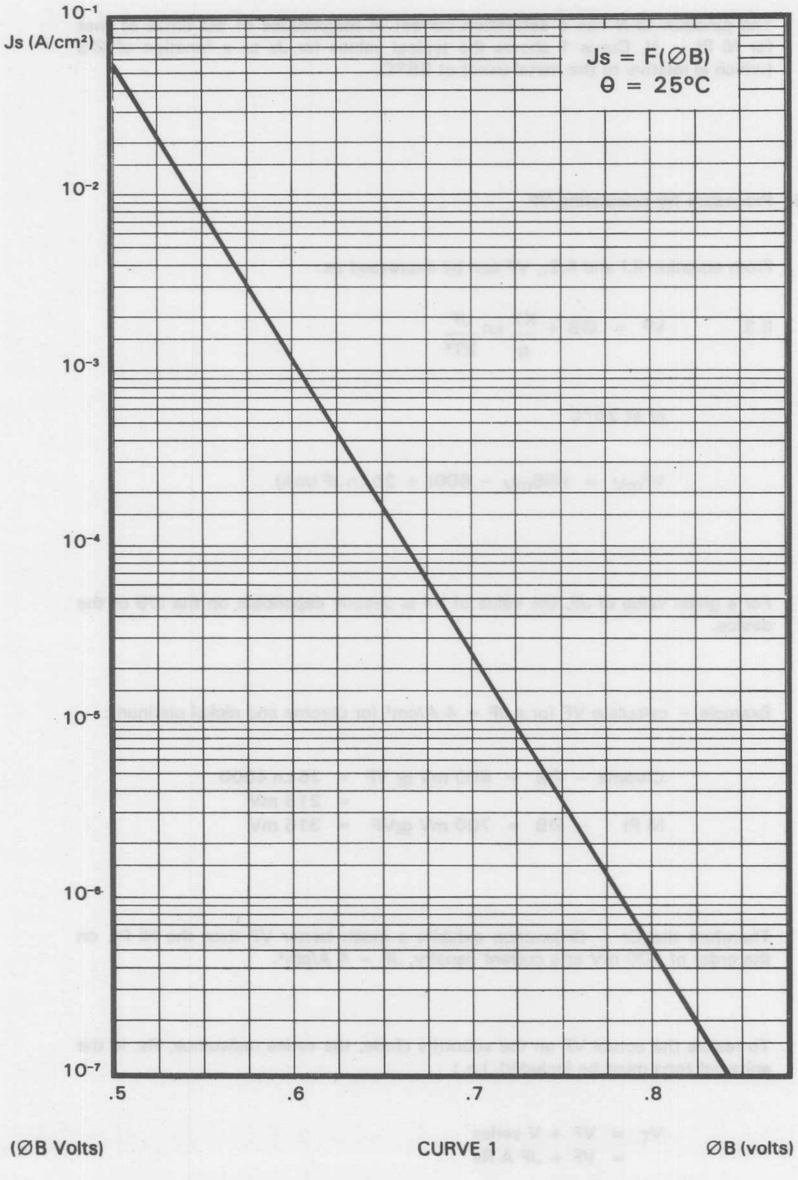
For the chrome, ØB = 0.6 eV

$$Js = 1.08\ (10^7) \times 9.5\ (10^{-11})$$

$$= 9.7\ (10^{-4})\ A/cm^2$$

$$Js = 1\ mA/cm^2$$

Therefore at 25°C, the nickel platinum's Js = 0.02 mA/cm² while the chrome exhibits Js = 1 mA/cm².



10^{-1}
Js (A/cm²)
Js = F(ØB)
θ = 25°C
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
.5
.6
.7
.8
(ØB Volts)
ØB (volts)

CURVE 1

The junction Cr-N has a saturation current in magnitudes of 50 times of that for Ni Pt – N. Curve 1 shows the typical values for Js as a function of ∅B (which is relative to the metal used) at 25°C.

b) **Procedure for calculating VF**

From equation II.I and II.2., VF can be expressed as:

II.3. $$VF = \varnothing B + \frac{KT}{q} \ln \frac{JF}{RT^2}$$

or at 25°C

$$VF_{mV} = (\varnothing B_{mV} - 600) + 26 \ln JF\,(mA)$$

For a given value of JF, the value of VF is directly dependent on the ∅B of the device.

Example – calculate VF for a JF = 4 A/cm² for chrome and nickel platinum:

Chrome – ∅B = 600 mV or VF = 26 Ln 4000
= 215 mV
Ni Pt – ∅B = 700 mV or VF = 315 mV

Therefore the Cr – Si junction exhibits a much better VF then the Ni Pt, on the order of 100 mV at a current density, JF = 4 A/cm².

To realize the actual VF on the schottky diode, the series resistance, Rs, in the epitaxial zone must be included, i.e.:

$$V_T = VF + V\ \text{series}$$
$$= VF + JF\,A\,Rs$$

Where: A = surface of the diode

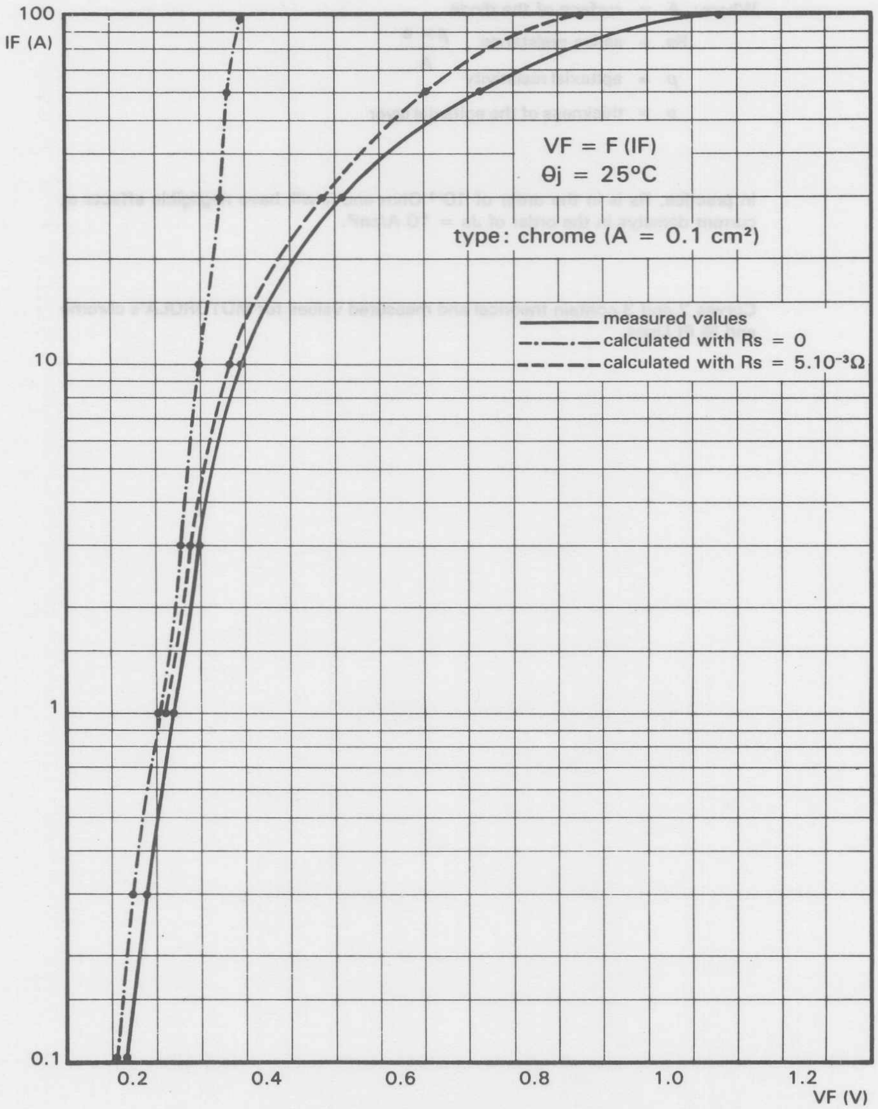
Rs = series resistance $\dfrac{\rho \times e}{A}$

ρ = epitaxial resistivity

e = thickness of the epitaxial layer

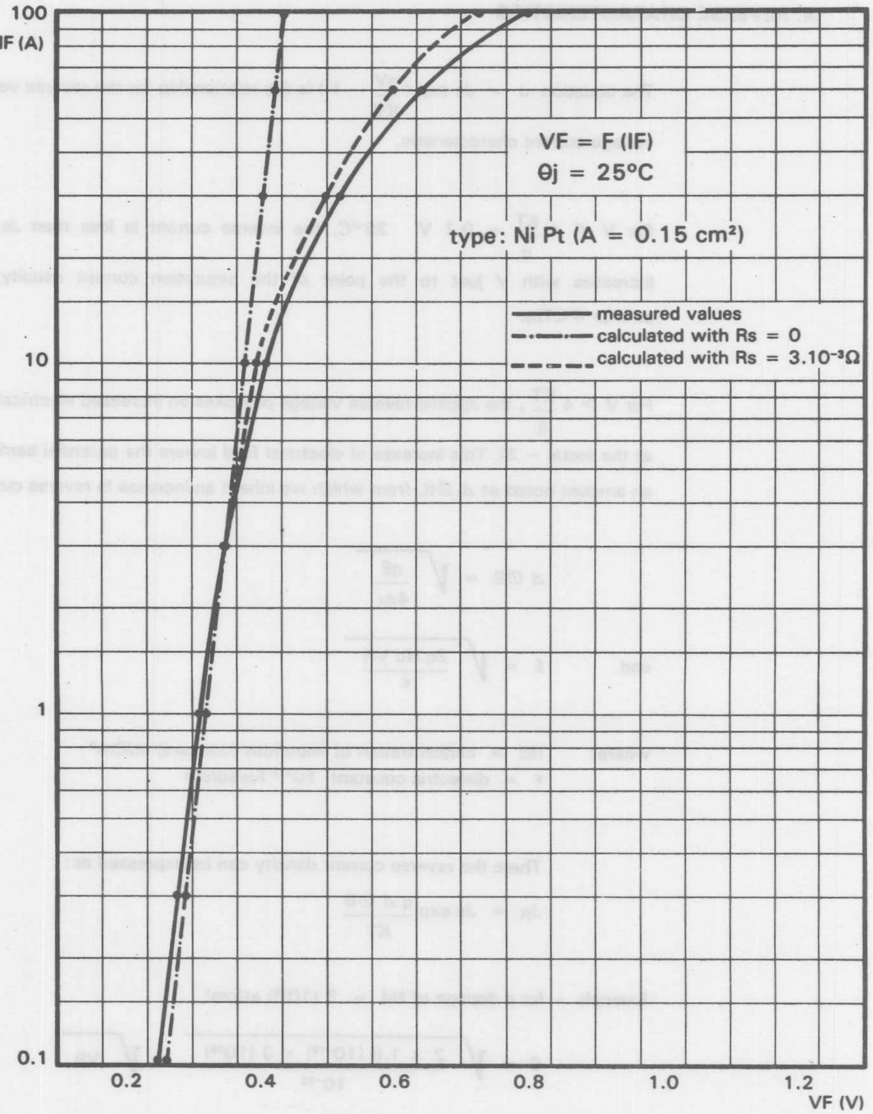
In practice, Rs is in the order of 10^{-3} Ohm and it will have negligible effects at current densitys in the order of Js = 10 A/cm².

Curves 2 and 3 contain theorical and measured values for MOTOROLA's chrome and Ni Pt Lines.



100
IF (A)
10
1
0.1
0.2
0.4
0.6
0.8
1.0
1.2
VF (V)
VF = F (IF)
θj = 25°C
type: chrome (A = 0.1 cm²)
measured values
calculated with Rs = 0
calculated with Rs = 5.10⁻³Ω

CURVE 2


100
IF (A)
10
1
0.1
0.2
0.4
0.6
0.8
1.0
1.2
VF (V)
VF = F (IF)
θj = 25°C
type: Ni Pt (A = 0.15 cm²)
measured values
calculated with Rs = 0
calculated with Rs = 3.10⁻³Ω

CURVE 3

III. REVERSE CHARACTERISTICS

The equation $J = Js \exp\left(\frac{qV}{KT} - 1\right)$ is the relationship for the reverse voltage voltage-current characteristic.

For $V < 4 \frac{KT}{q} = 0.1$ V 25°C, the inverse current is less than Js, but increases with V just to the point of the saturation current density, Js, at $V \geqslant 4$ KT/q.

For $V > 4 \frac{KT}{q}$, the applied reverse voltage provokes an increased electrical field at the metal – Si. This increase of electrical field lowers the potential barrier by an amount noted as $\Delta\ \varnothing B$, from which we inherit an increase in reverse current.

$$\Delta\ \varnothing B = \sqrt{\frac{qE}{4\pi\epsilon}}$$

and
$$E = \sqrt{\frac{2q\ Nd\ VR}{\epsilon}}$$

where: Nd = concentration of impurities (donners) at/Cm³
ϵ = dielectric constant 10^{-12} Farad/cm

There the reverse current density can be expressed as:

$$J_R = Js \exp \frac{q \Delta\ \varnothing B}{KT}$$

Example – for a dopage of Nd = $3\ (10^{15})$ at/cm³

$$E = \sqrt{\frac{2 \times 1.6\ (10^{-19}) \times 3\ (10^{15})}{10^{-12}}} \times \sqrt{VR}$$

$$E = 3\ (10^{4}) \sqrt{VR}$$

and $$\Delta \varnothing B = \frac{1.6\,(10^{-19}) \times 3\,(10^{4})}{4\,\pi\,(10^{-12})} \times \sqrt[4]{VR}$$

$$\Delta \varnothing B = 0.019 \sqrt[4]{VR}$$

To retrieve the value of IR at VR = 5 V

$$\Delta \varnothing B = 0.019 \sqrt[4]{5} = 0.02\ V$$

$$JR = Js \exp \frac{q\,\Delta \varnothing B}{KT}$$

$$= Js \exp 28/26$$

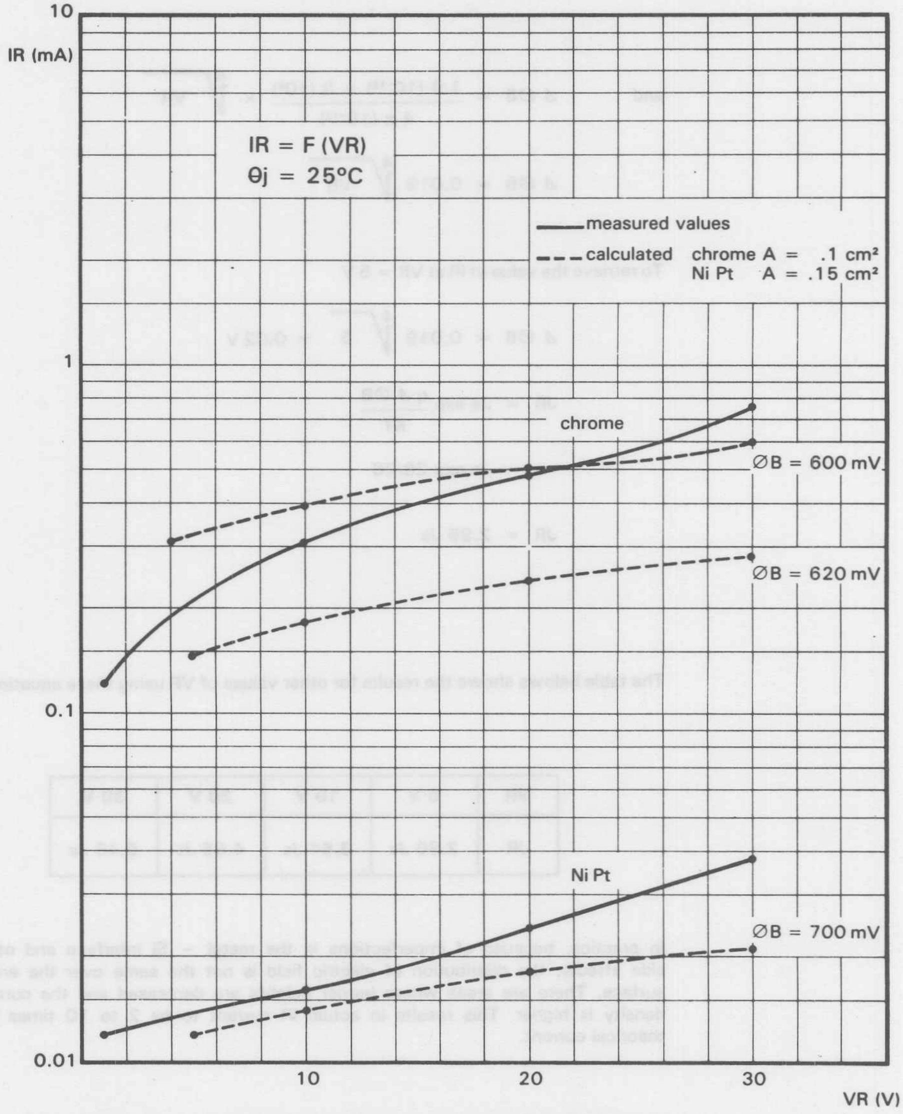
$$JR = 2.96\ Js$$

The table belows shows the results for other values of VR using these equations:

VR	5 V	10 V	20 V	30 V
JR	2.96 Js	3.64 Js	4.65 Js	5.48 Js

In practice, because of imperfections in the metal – Si interface and other side effects, the distribution of electric field is not the same over the entire surface. There are areas where barrier heights are decreased and the current density is higher. This results in actual IR current to be 2 to 10 times the theorical current.

Curve 5 permits the comparison of theorical and actual measured values o as a function of VR for both the chrome and the Ni Pt schottky.


10
IR (mA)
IR = F (VR)
θj = 25°C
measured values
calculated
chrome A = .1 cm²
Ni Pt A = .15 cm²
1
chrome
ØB = 600 mV
ØB = 620 mV
0.1
Ni Pt
ØB = 700 mV
0.01
10
20
30
VR (V)

CURVE 4

IV. TEMPERATURE INFLUENCES

a) **Variation in VF as a function of temperature**

$$VF = \varnothing B + \frac{KT}{q} \mathrm{Ln} \frac{JF}{RT^2}$$

$$VF = \varnothing B - \frac{KT}{q} \mathrm{Ln}\, RT^2 + \frac{KT}{q} \mathrm{Ln}\, JF\,(mA)$$

$$VF = \varnothing B - A + U\, \mathrm{Ln}\, JF\,(mA)$$

Where A and U are given in the table below:

θ°C	25	50	75	100	125	150
A(mV)	600	656	709	765	819	876
U(mV)	26	28.2	30.3	32.5	34.6	36.8

For JF = 100 mA/cm² the Δ VF = 45 mV/°C
1 A/cm² 40 mV/°C
10 A/cm² 35 mV/°C
100 A/cm² 30 mV/°C

b) **Variation of JS with temperature**

$$Js = RT^2 \exp \frac{-q\, \varnothing B}{KT}$$

$$Js = B \exp \frac{-\varnothing B}{U}$$

θ°C	25	50	75	100	125	150
B 10^7 A	1.08	1.27	1.47	1.69	1.92	2.17
U(mV)	26.0	28.2	30.3	32.5	34.6	36.8

In the particular cases of Cr and Ni Pt, Js is found to be:

TABLE A

Js(mA) \ θ°C	25	50	75	100	125	150
Cr ØB = 600 mV	1.0	7.3	37	162	565	1800
NiPt ØB = 700 mV	.022	.021	1.41	7.5	31.0	119

c) **Variation of Js with temperature**

$$JR = Js \exp \frac{q \Delta \varnothing B}{KT}$$

The table below gives the value for the multiplier coefficient

$M = \exp \dfrac{q \Delta \varnothing B}{KT}$ as a function of VR and temperature.

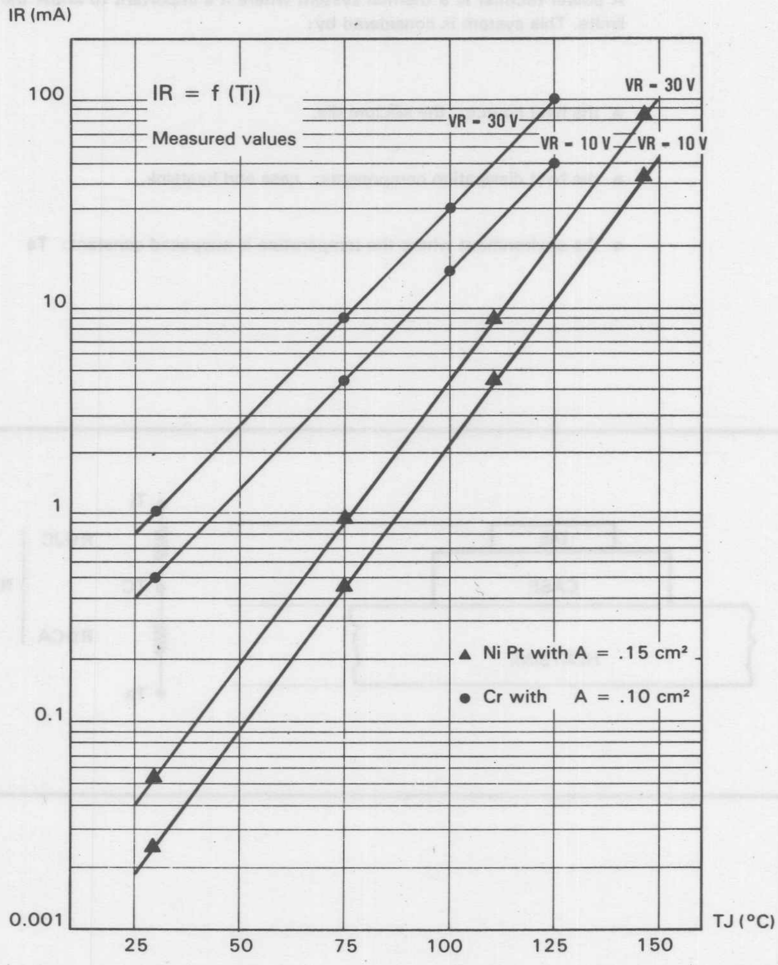
TABLE B

VR \ θ°C	25	50	75	100	125	150
5 V	2.96	2.72	2.54	2.38	2.26	2.15
10 V	3.64	3.29	3.03	2.81	2.64	2.49
20 V	4.65	4.12	3.74	3.42	3.17	2.96
30 V	5.48	4.80	4.30	3.90	3.59	3.32

To calculate the effective IR find Js from TABLE A and the multiplier coefficient M given in table B

$$JR = M \times Js$$

Actual reverse current for MOTOROLA devices are shown on curve 6 as a function of temperature for Cr and Ni Pt.

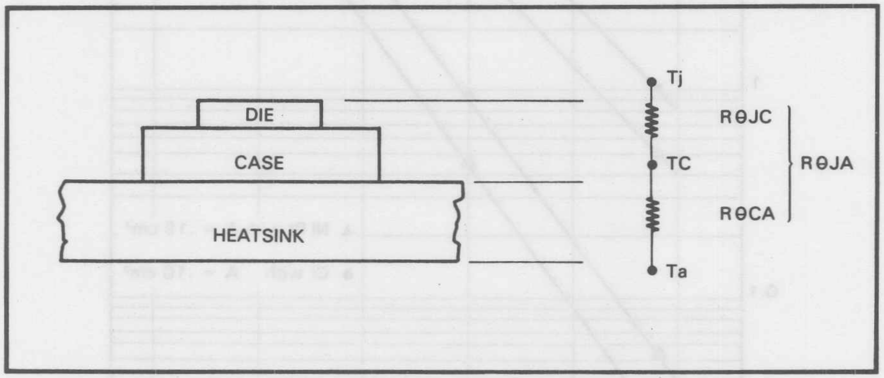

IR (mA)
IR = f (Tj)
Measured values
VR = 30 V
VR = 30 V
VR = 10 V
VR = 10 V
100
10
1
0.1
0.001
▲ Ni Pt with A = .15 cm²
● Cr with A = .10 cm²
25
50
75
100
125
150
TJ (°C)

CURVE 5

V. SCHOTTKY DIODES THERMAL STABILITY

A power rectifier is a thermal system where it's important to know the stability limits. This system is considered by:

- the heat source: the silicium die,
- the heat dissipation components: case and heatsink,
- the environment where the temperature is supposed constant: Ta



Stability Conditions

Power evacuated outside must be equals to the dissipated power in the die, then thermal stability equation is:

$$\frac{Tj - Ta}{R_{\theta JA}} = PF + PR\ (Tj)$$

With PF = dissipated power in forward conduction (quite independent of Tj)

PR = dissipated power in reverse (it is a function of Tj)

The condition of thermal stability is:

$$\frac{d\ PR\ (Tj)}{d\ Tj} < \frac{1}{R_{\theta}}$$

Stability Limit

In a diode, reverse current variation with the temperature must be represented in first approximation by the equation:

$$IR = I_1 \exp C\ Tj$$

Then we have

$$PR = VR \times I_1 \exp C\ Tj$$

And

$$\frac{d\ PR}{d\ Tj} = C\ PR$$

And at the stability limit:

$$C\ PRm = \frac{1}{R_{\theta JA}}$$

At the stability limit, the value of the reverse current will be:

$$\boxed{IRm = \frac{1}{C\, R_{\theta JA}\, VR}}$$

Maximal junction temperature will be:

$$\boxed{Tjm = \frac{1}{C}\, Ln\, \frac{IRm}{I_1}}$$

And the maximal ambient temperature:

$$\boxed{Tam = Tjm - PF\, R_{\theta} - \frac{1}{C}}$$

For each value of Ta < Tam, the diode will be thermally stable, the junction temperature value will be below Tjm and the leakage current IR lower than the limit value IRm.

For MOTOROLA diodes family, the value of C is quite constant ($\simeq 0.05$), it is therefore interesting to notice the maximal value of admissible IR is directly determined by use co ditions.

NOTE: when the solution θm we had is higher than θj max value, we must consider that $\theta m = \theta j$ max.

And then $\theta am = \theta j\ max - R\theta\ VR\ IRm$

With IRm = IR at $\theta = \theta j$ max

Example: for a mounting where the heatsink used is $R_{\theta JA} = 10°C/W$ and where the reverse voltage applied is VR = 30 V, the running maximum IR admissible will be:

$$IRm = \frac{1}{0.05 \times 10 \times 30} = 66\ mA$$

A measure of this current made on the functionning circuit in the worst conditions of charge and ambient temperature will allow to evaluate the security edge with regard to this limit.

In this same application, if we use a diode with I1 = 0.3 mA (experimental measurement), the thermal stability limit temperatures will be:

$$Tj = \frac{1}{0.05} \text{ Ln } \frac{66}{0.3} = 108°C$$

$$\text{Ta max} = 88°C - PF \times 10$$

If forward dissipated power is PF = 2 Watts, the maximum ambient temperature will be:

$$\text{Ta max} = 68°C$$

Use of Data Sheets

MOTOROLA data sheets give directly the graphic solution of the stability limit calculations that we just made.

Generally the running diode is not submitted to a continue reverse voltage but to a square or sinusoïdal signal. The reverse voltage which must be consider is the equivalent VR voltage:

$$\text{VR equi} = \text{VR peak} \times F$$

The parameter F to use is given in the data sheets.

Therefore the average forward dissipated power value PF must be evaluated taking into account the average current value IF (AV) and the form of the signal.

The set of curves presented in the data sheets allow to determine the ambient temperature Tam in two steps:

1. **From VR and RΘ,** evaluation of the reference temperature (TR)

2. **From TR and PF, determine Tam value.**

VI. MOTOROLA'S DEVICE FAMILY AND QUALITY/ RELIABILITY PROGRAM

MOTOROLA offers a wide range of schottky products ranging from 1 A plastic packages to the powerfull 75 A DO-5 with possibilities in chrome or Ni Pt, depending on the package / current requirement, with voltage ranges to 40, 50 Volts VR.

A high volume production is achieved by integrating a Quality Control monitoring at each step of operation. Long term reliability is assured by a continuous Line Audit program with life test including mechanical, thermal and electrical stresses.

I. USE OF SCHOTTKY DIODES IN THE SWITCHMODE POWER SUPPLY

Us of schottky diodes in the continue to continue converter of a switching power supply allows:

- To decrease forward and switching power losses. Heatsinks used will be smaller, design of power supply will be more compact and the operating temperature lower.

- To decrease the stresses applied on the switching transistor and then to have a better reliability from the whole.

The subject of this study is to determine the operating conditions of the diodes used in the main configurations generally required in:

- Flyback converter

- Forward converter

The full knowledge of these conditions will allow the choice of an optimal product among our schottky diode family.

II. FLYBACK CONVERTER

In this type of converter (see diagram in figure 1), the power is accumulated in the primary of the transformer when the transistor is under conduction. The power is transfered to the load thru the diode D which becomes conductive when the transistor is blocked.

Figure 2 gives the diagram of voltages and currents as a function of time.

II.I. Forward Current in the Diode

The average current in the rectifying diode IF (AV) is equal to the current Io provided to the load. However the instantaneous value of the current IF (t) can reach a maximum value relatively high (IF max) that is important to estimate.

We must have $$\text{IF (AV)} = \text{Io}$$

And then on one period $$\text{T Io} = \int_{0}^{T} \text{IF (t) dt}$$

The diagram of the current IF (figure 2) allow to write:

$$\text{T Io} = \frac{T - \zeta}{2} \text{ (IF max + IF min)}$$

Then $$\text{IF max} = \frac{2T}{\zeta - T} \text{ Io} - \text{IF min}$$

Using $$\frac{\zeta}{T} = \delta$$

We have $$\text{IF max} = \frac{2 \text{ Io}}{\delta\text{max} - 1} - \text{IF min}$$

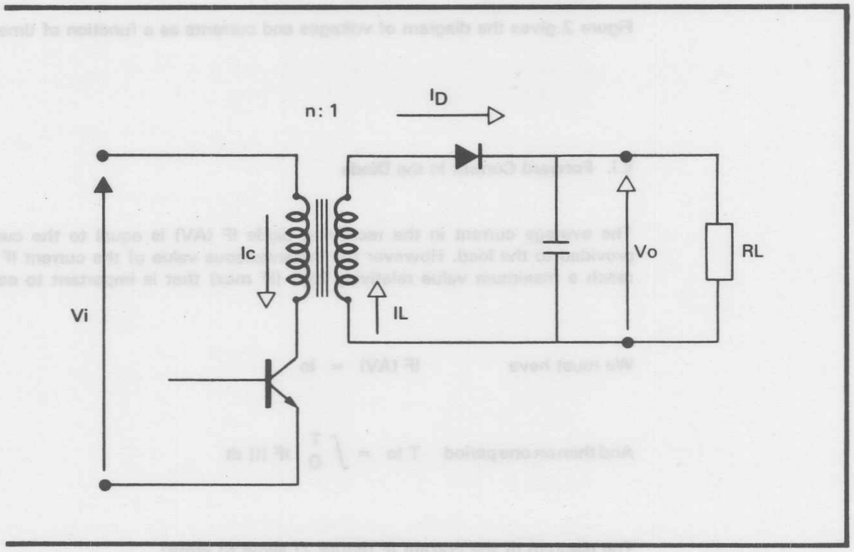


FIGURE 1 : FLYBACK CONVERTER DIAGRAM

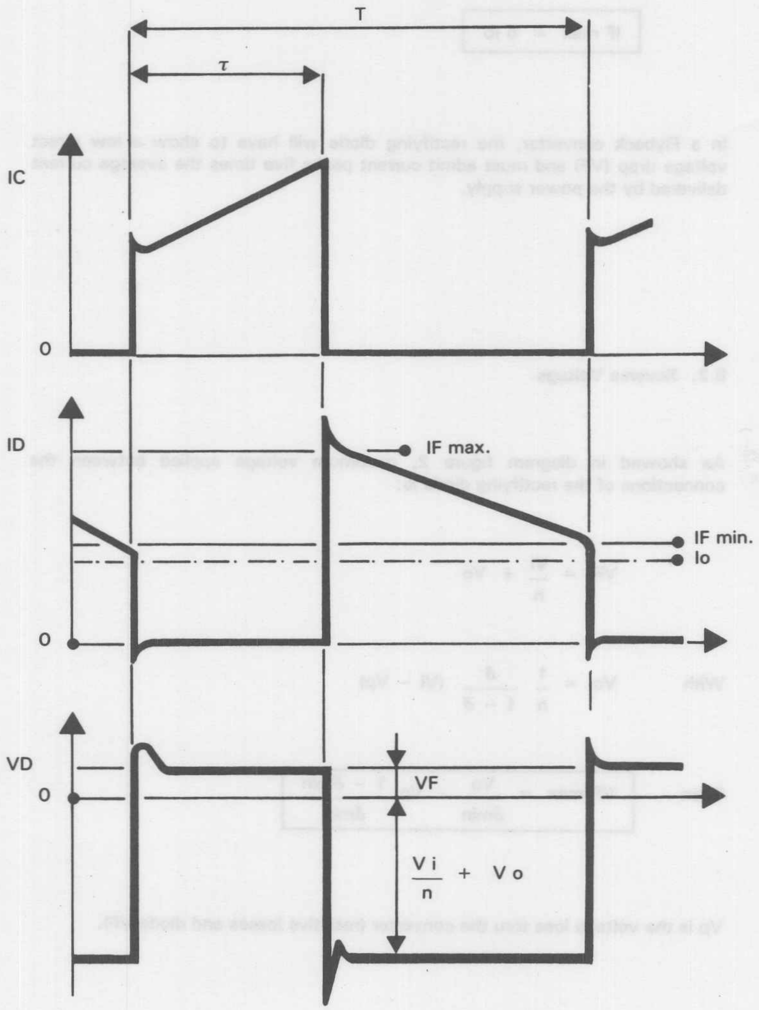


FIGURE 2 : VOLTAGES AND CURRENTS DIAGRAM IN A FLYBACK CONVERTER

In the most unfavourable conditions IF min = 0 and for a maximum value of $\delta = 0.6$, we can therefore reach:

$$\boxed{IF\ max = 5\ Io}$$

In a Flyback converter, the rectifying diode will have to show a low direct voltage drop (VF) and must admit current peaks five times the average current delivered by the power supply.

II.2. Reverse Voltage

As showed in diagram figure 2, maximum voltage applied between the connections of the rectifying diode is:

$$VR = \frac{Vi}{n} + Vo$$

With $$Vo = \frac{1}{n} \frac{\delta}{1 - \delta} (Vi - Vp)$$

Then $$\boxed{VR\ max = \frac{Vo}{\delta min} - Vp \frac{1 - \delta min}{\delta min}}$$

Vp is the voltage loss thru the converter (resistive losses and diode VF).

One generally chooses a diode with VRRM equals to $\frac{Vo}{\delta min}$ plus 20% in order to take care of loss and peak voltages at the switching point.

III. FORWARD CONVERTER

In this type of converter (figure 3) power is directly transfered to the load through the diode D1 and the self Lo when the transistor is on.

When the transistor is blocked, power stocked in Lo at the previous phase, is transfered to the load by the free wheel diode D2.

Figure 4 gives the diagram of currents ID 1 and ID 2.

III.1. Direct Currents in D 1 and D 2 Diodes

a) ESTIMATED AMPLITUDE OF CURRENT PEAK IF MAX

The average current which passes thru Lo is equal to the Io current delivered by the power supply.

For a period T, we can write:

$$T\ Io = \int_{O}^{T} I_2\ (t)\ dt$$

$$T\ Io = \frac{T}{2}\ (IF\ max + IF\ min)$$

$$Io = \frac{1}{2}\ (IF\ max + IF\ min)$$

$$IF\ max = 2\ Io - IL\ min$$

For the limit conditions when IF min = 0, we therefore reach the maximum value:

$$\boxed{IF\ max = 2\ Io}$$

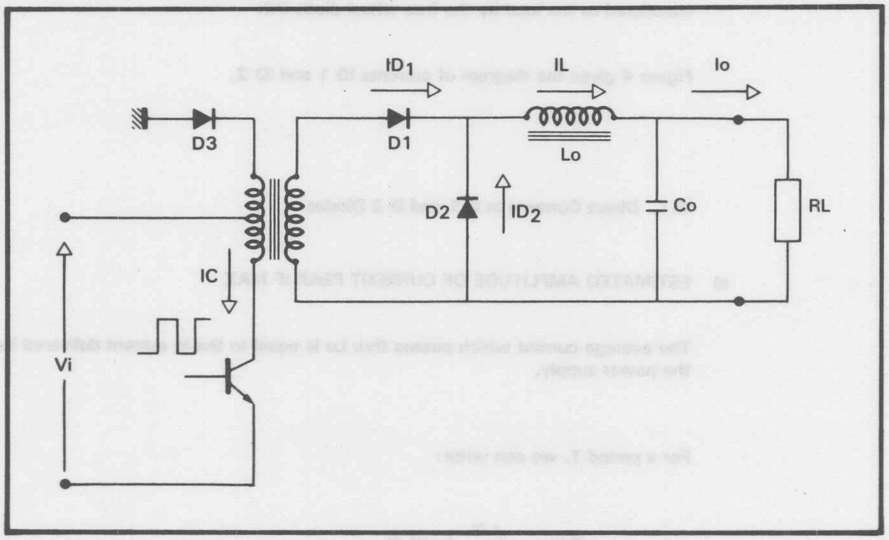


FIGURE 3 : FORWARD CONVERTER DIAGRAM

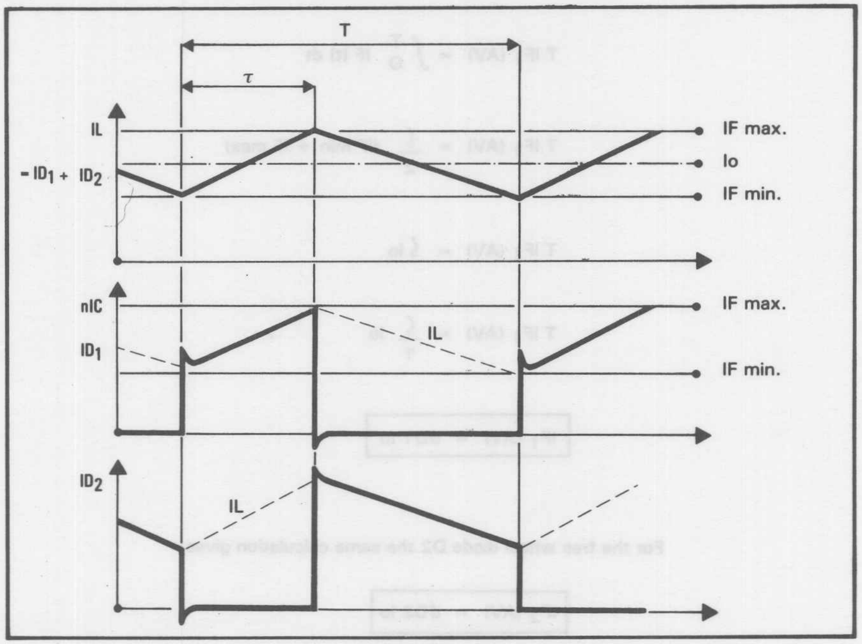


FIGURE 4 : CURRENTS DIAGRAM IN A FORWARD CONVERTER

b) AVERAGE CURRENT IF (AV)

For the rectifying diode D1, on the T period:

$$T\,IF_1\,(AV) = \int_0^T IF\,(t)\,dt$$

$$T\,IF_1\,(AV) = \frac{\zeta}{2}\,(IF\,min + IF\,max)$$

$$T\,IF_1\,(AV) = \zeta\,Io$$

$$T\,IF_1\,(AV) = \frac{\zeta}{T}\,Io$$

$$\boxed{IF_1\,(AV) = \delta D1\,Io}$$

For the free wheel diode D2 the same calculation gives:

$$\boxed{IF_2\,(AV) = \delta D2\,Io}$$

III.2. Reverse Voltage

As in Flyback converter (see § II.2.) D1 and D2 diodes will have to hold:

$$\boxed{VRRM \geqslant \frac{Vo}{\delta min} + 20\%}$$

IV. CHOICE OF A DIODE/THERMAL STABILITY CONDITION

For determining the size for the diodes required, we must take into account:

- Maximum value of reverse voltage VRRM.
- Average value of direct current IF (AV) and its repetitive peak IF max value.

With this first choice done, it is important to verify the thermal stability conditions which will determine the maximum ambient temperature required for reliable operation of the device (see § A.V.).

As described on all MOTOROLA data sheets, thermal stability conditions take into account:

- Reverse power dissipation
- Forward power dissipation

IV.1. Reverse Dissipation

From the maximum value of VR (t), it is convenient to calculate an equivalent continuous reverse voltage VR (equi) which would give the same dissipation.

We must therefore have, on a T period:

$$VR\,(equi) \times IR\,(equi) \times T = VRM \times IRM \times (T - \tau)$$

Making the approximation IR = K VR (very unfavourable case) it is possible to write:

$$VR^2\,(equi) \times K \times T = VRM^2 \times K \times (T - \tau)$$

And then $$VR\,(equi) = VRM - \sqrt{1 - \delta D}$$

IV.2. Forward Dissipation

Direct current is a rectangular signal of maximum amplitude equal to IFM and of an average value IF (AV).

$$\text{IFM} = \frac{\text{IF (AV)}}{\delta \text{ D}}$$

Dissipated power is $\text{PF (AV)} = \text{IFM} \times \text{Vfm} \times \delta \text{ D}$

And $\quad \text{PF (AV)} = \text{IF (AV)} \times \text{VFM}$

with VFM value of VF for $\text{IF} = \dfrac{\text{IF (AV)}}{\delta \text{ D}}$

IV.3. Stability Conditions Verification

From the values found for VR (equi) and PF (AV), the set of curves given in MOTOROLA schottky diodes data sheets will allow to determine the maximum ambient operating temperature.

IV.4. Results Summary

<table>
<tr><th rowspan="2"></th><th rowspan="2">Flyback</th><th colspan="2">Forward</th></tr>
<tr><th>Rectifying Diode D1</th><th>Free Wheel Diode D2</th></tr>
<tr><td>MAXIMAL REVERSE VOLTAGE VRRM</td><td colspan="3">$\dfrac{\text{Vo}}{\delta \text{ min}} + 20\ \%$</td></tr>
<tr><td>EQUIVALENT REVERSE VOLTAGE VR (equi)</td><td>$\text{VRRM} \times \sqrt{\delta \text{ min}}$</td><td>$\text{VRRM} \sqrt{1 - \delta\text{min}}$</td><td>$\text{VRRM} \times \sqrt{\delta \text{ min}}$</td></tr>
<tr><td>MAXIMAL REPETITIVE FORWARD CURRENT IF max</td><td>5 Io</td><td>2 Io</td><td>2 Io</td></tr>
<tr><td>AVERAGE FORWARD CURRENT</td><td>Io</td><td>$\text{Io} \times \delta \text{ max}$</td><td>$\text{Io} \times (1 - \delta \text{ min})$</td></tr>
<tr><td rowspan="2">AVERAGE FORWARD DISSIPATION PF (AV)</td><td colspan="3">PF (AV) = IF (AV) × VFM with VFM = VF at IF =</td></tr>
<tr><td>$\dfrac{\text{IF (AV)}}{1 - \delta \text{ max}}$</td><td>$\dfrac{\text{IF (AV)}}{1 - \delta \text{ min}}$</td><td>$\dfrac{\text{IF (AV)}}{1 - \delta \text{ max}}$</td></tr>
</table>

V. USE EXAMPLES

V.1. Flyback converter = 5 V / 5 A

Assume a converter with:

δ min = 0.37
δ max = 0.50

Then the table in § IV.4. gives:

VRRM = 16.0 Volts
VR (equi) = 9.7 Volts
IFM = 25 A
IF (AV) = 5 A

One must use a product 15 A, 30 V: BYS 16-30

PF (AV) = 5 – (VF à 10 A)
= **2 Watts**

A heatsink with $R_{\theta JA}$ = 20° C/W is sufficient enough. The data sheet gives TR = 105° C, and the maximum ambient operating temperature will be:

$$TA = TR - PF\,(AV) \times R_{\theta JA} = 65°C$$

V.2. Flyback converter = 5 V / 12 A

Assume a converter with:

δ min = 0.35
δ max = 0.50

Then the table in § IV.4. allows to calculate the following parameters:

VRRM = 17 Volts
VR (equi) = 10 Volts

$IFM = 60\ A$
$IF\ (AV) = 12\ A$

With a relatively **high** value of VR (equi) **voltage** we must choose a 30 V product of Ni PT serie: BYS 35-30, and then:

$$PF\ (AV) = 12 \times (VF \text{ at } 24\ A) = 6 \text{ Watts}$$

We will choose a heatsink with a total thermal resistivity $R_{\theta JA} = 10°\ C/W$. BYS 35-30 data sheet therefore gives the reference temperature $TR = 130°\ C$, and the maximum ambient temperature:

$$TA = TR - PF\ (AV) \times R_{\theta JA} = 64°\ C$$

V.3. Forward converter = 5 V / 40 A

If the converter is such that:

δ min = 0.35
δ max = 0.50

Table (§ IV.4.) allows to determine the main parameters of use for rectifying and free wheeling diodes.

	RECTIFIYING DIODE D1	FREE WHEEL DIODE D2
VRRM	17 V	17 V
VR (equi)	13 V	10 V
IF max	80 A	80 A
IF (AV)	20 A	26 A

For rectifying and free wheeling diodes, we will prefer a BYS 60-30 product.

Direct supply power will be:

$$PF\ (AV)\ D1 = 20 \times (VF\ at\ 57\ A) = 11.0\ W$$
$$PF\ (AV)\ D2 = 26 \times (VF\ at\ 52\ A) = 13.5\ W$$

With a heatsink of $R_{\theta JA} = 5°\,C/W$ for each diode the operating temperature will be lower than 62° C.

VI. SCOPE OF USE

From the product characteristics given by the data sheet and use conditions (see § IV.4.) it is possible to determine for each diode a scope of use.

Figure 5 defines these scopes in the particular case of a 5 V power supply, as a function of the power delivered by the supply.

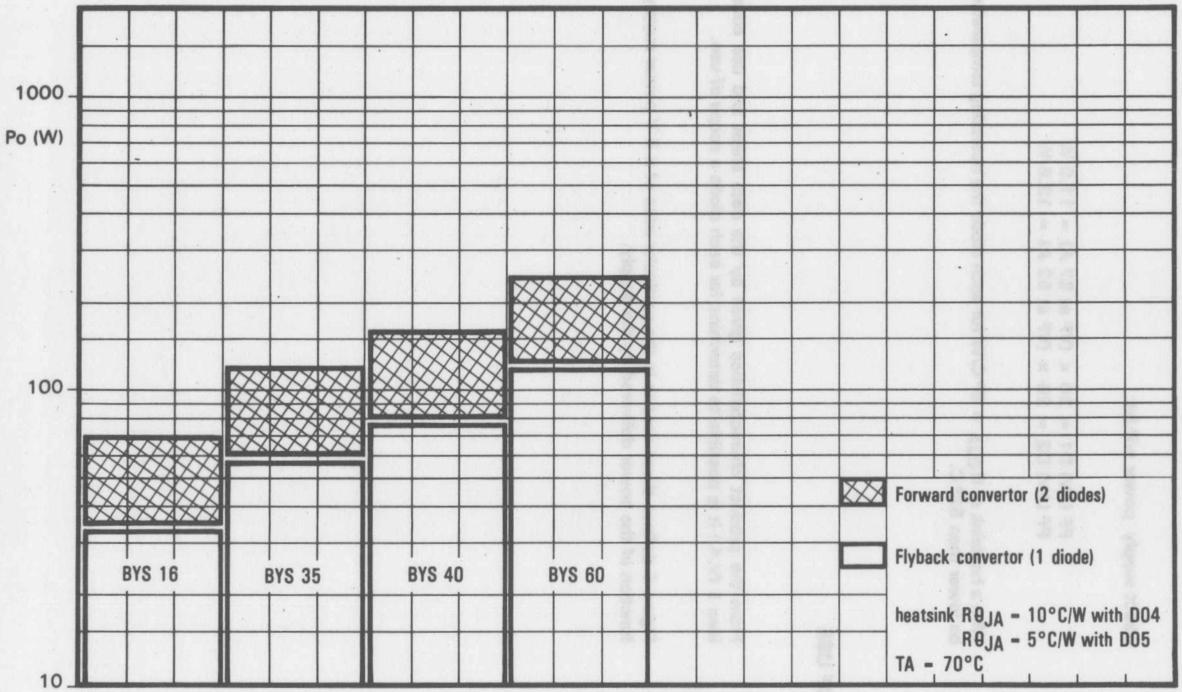


FIGURE 5: PARTICULAR CASE OF A POWER SUPPLY Vo = 5 V
CHOICE OF A DIODE TYPE FUNCTION OF THE POWER DELIVERED

TECHNOLOGY PERFORMANCES

TECHNOLOGY

PERFORMANCES

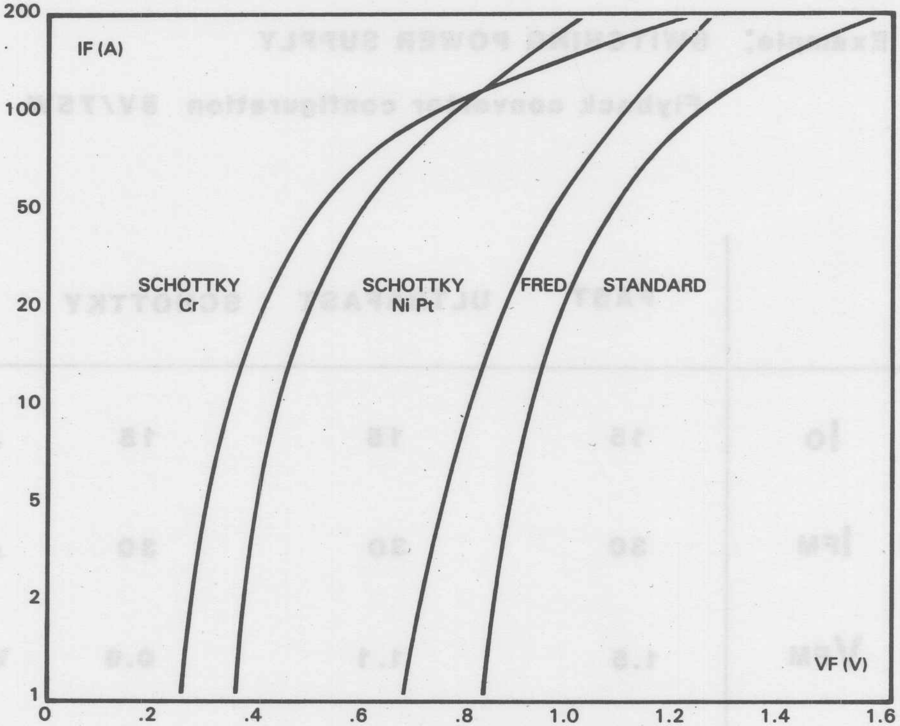
	SCHOTTKY	ULTRAFAST	FAST
typ REVERSE VOLTAGE (Vr)	50v	200v	800v
typ FORWARD VOLTAGE (Vf)	0.5v	0.8v	1.1v
typ RECOVERY TIME (Trr)	10ns	30ns	100ns

FORWARD LOSSES

Example: SWITCHING POWER SUPPLY

Flyback convertor configuration 5V/75W

	FAST	ULTRAFAST	SCHOTTKY	
I_O	15	15	15	A
I_{FM}	30	30	30	A
V_{FM}	1.5	1.1	0.6	V
P_{FAV}	22.5	16.5	9	W
%Losses	30%	22%	12%	



COMPARISON OF FORWARD VOLTAGE DROP FOR DIFFERENT TECHNOLOGIES
(THESE CURVES REFERED TO THE DIE AREA A = .16 mil²)

RECTIFIER PRODUCT RANGE

MOTOROLA SG EUROPE

MOTOROLA EXTENDS ITS RECTIFIER PRODUCT RANGE

WITH THE INTRODUCTION OF :

SUPER FAST RECTIFIERS 100 nanosecond recovery time

1 Amp axial lead	TSA4933	serie	50 volts to 600 volts
3 Amp axial lead	TSA850	serie	50 volts to 600 volts

ULTRA FAST EPITAXIAL RECTIFIERS 35 nanosecond recovery time

1 Amp axial lead	MUR105	serie
8 Amp TO220	MUR805	serie single chip
2x8 Amp TO220	MUR1605	serie dual chips
15 Amp DO4	BYW81-50, BYW30-50 series	

SCHOTTKY BARRIER RECTIFIERS

7 Amp TO220	MBR735	serie single chip
10 Amp TO220	MBR1020	serie single chip
2x7,5 Amp TO220	MBR1520CT	serie dual chips
2x10 Amp TO220	MBR2020CT	serie dual chips

AUTOMOTIVE TRANSIENT SUPPRESSOR

6 Amp axial lead MR2520L avalanche voltage 24-32 volts IFSM : 400 Amp

MOTOROLA RECTIFIERS

SUPER FAST RECOVERY DIODES

SERIES	TSA4933	TSA850	BYX50	BYX61	MR2102	BYX65	MR5102
VRRM 50	TSA4933	TSA850		BYX61-50		BYX65-50	
100	TSA4934	TSA851		BYX61-100		BYX65-100	
200	TSA4935	TSA852	BYX50-200	BYX61-200	MR2102	BYX65-200	MR5102
300			BYX50-300	BYX61-300		BYX65-300	
400	TSA4936	TSA854		BYX61-400	MR2104	BYX65-400	MR5104
500							
600	TSA4937	TSA856			MR2106		MR5106
800					MR2108		MR5108
AVERAGE FORWARD CURRENT IF(AV)	1 A	3 A	7 A	12 A	12 A	30 A	50 A
REVERSE RECOVERY TIME MAX NSEC	100 nsec	100 nsec	100 nsec	100 nsec	100 nsec	100 nsec	100 nsec
							
CASE	59-04	267	DO4	DO4	DO4	DO5	DO5

DO4/DO5 REVERSE TYPES AVAILABLE

MOTOROLA RECTIFIERS

ULTRA FAST RECOVERY EPITAXIAL DIODES

SERIES	MUR105	BYW29	BYW80	MUR805	BYW51	MUR1605CT	BYV32
VRRM 50	MUR105	BYW29-50	BYW80-50	MUR805	BYW51-50	MUR1605CT	BYV32-50
100	MUR110	BYW29-100	BYW80-100	MUR810	BYW51-100	MUR1610CT	BYV32-100
150	MUR115	BYW29-150	BYW80-150	MUR815	BYW51-150	MUR1615CT	BYV32-150
AVERAGE FORWARD CURRENT IF(AV)	1 A	7 A	7 A	8 A	2X8 A *	2X8 A *	2X10 A
REVERSE RECOVERY TIME MAX NSEC	35 nsec	35 nsec	35 nsec	35 nsec	35 nsec	35 nsec	35 nsec
							
CASE	DO41	TO220AC	TO220AC	TO220AC	TO220AB	TO220AB	TO220AB

* 8 AMPS PER LEG

MOTOROLA

SEMICONDUCTORS

P.O. BOX 20912 • PHOENIX, ARIZONA 85036

MUR105
MUR110
MUR115

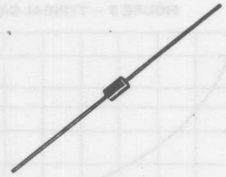
SWITCHMODE POWER RECTIFIERS

. . . designed for use in switching power supplies, inverters, and as free wheeling diodes, these devices have the following features:

- 35 ns Recovery Time
- Low Forward Voltage
- Low Leakage Current
- DO-41 Glass Package

ULTRAFAST RECTIFIERS

1 AMPERE
50-150 VOLTS



MAXIMUM RATINGS

Rating	Symbol	MUR105	MUR110	MUR115	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	150	Volts
Average Rectified Forward Current (Rated V_R) $T_L = 135°C$, L = 3/8" $T_A = 65°C$, L = 3/8", (Mt. Method #1)	$I_{F(AV)}$		1.0 1.5		Amps
Peak Repetitive Forward Current $T_L = 135°C$, L = 3/8" (Rated V_R, Square Wave, 20 kHz)	I_{FRM}		2.0		Amps
Nonrepetitive Peak Surge Current (Surge applied at rated load conditions halfwave, single phase, 60 Hz)	I_{FSM}		35		Amps
Operating Junction and Storage Temperature	T_J, T_{stg}		-65 to +175		

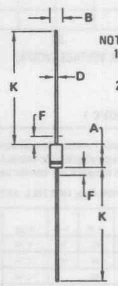
THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Thermal Resistance, Junction to Lead = 3/8"	$R_{\theta JL}$	45	50	°C/W

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Instantaneous Forward Voltage (1) ($I_F = 3.14$ A, $T_J = 150°C$) ($I_F = 1.0$ A, $T_J = 25°C$)	v_F	 0.800 0.800	 0.860 0.875	Volts
Reverse Current (Rated dc Voltage, $T_J = 150°C$) (Rated dc Voltage, $T_J = 25°C$)	i_R	 37 0.9	 50 2.0	μA
Reverse Recovery Time ($I_F = 1.0$ A, di/dt = 50 A/μs, $I_{REC} = 0.1$ A) ($I_F = 0.5$ A, $I_R = 1.0$ A, $I_{REC} = 0.25$ A)	t_{rr}	 29 20	 35 25	ns
Forward Recovery Voltage ($I_F = 1.0$ A, di/dt = 100 A/μs, Recovery to 1.0 V)	V_{fr}	3.5	5.0	Volts
Forward Recovery Time ($I_F = 1.0$ A, di/dt = 100 A/μs, Recovery to 1.0 V)	t_{fr}	15	25	ns

(1) **Pulse Test:** Pulse Width = 300 μs, Duty Cycle ≤ 2.0%
Switchmode is a trademark of Motorola Inc.



NOTE:
1. POLARITY DENOTED BY CATHODE BAND
2. LEAD DIAMETER NOT CONTROLLED WITHIN "F" DIMENSION.

All JEDEC dimensions and notes apply.

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	4.07	5.20	0.160	0.205
B	2.04	2.71	0.080	0.107
D	0.71	0.86	0.028	0.034
F	–	1.27	–	0.050"
K	27.94	–	1.100	–

DO-41
CASE 59-03

MECHANICAL CHARACTERISTICS

CASE: Glass.

FINISH: External leads are plated and are readily solderable

POLARITY: Cathod indicated by polarity band.

WEIGHT: 0.4 Gram (approximately).

MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 240°C, 1/8" from case for 10 seconds at 5.0 lbs. tension.

FIGURE 1 — MAXIMUM FORWARD VOLTAGE

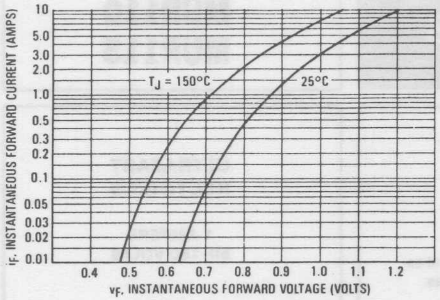


FIGURE 2 — CURRENT DERATING, PRINTED CIRCUIT BOARD MOUNTING

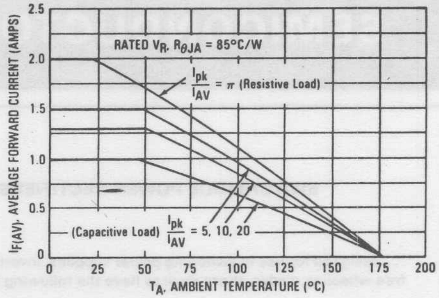


FIGURE 3 — TYPICAL CAPACITANCE

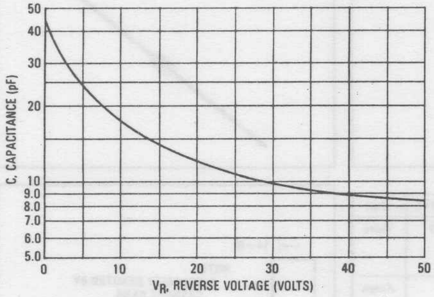
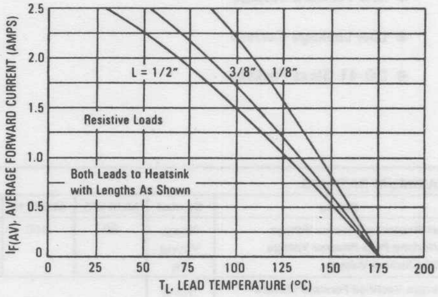


FIGURE 4 — CURRENT DERATING versus LEAD TEMPERATURE



NOTE 1

Data shown for thermal resistance junction-to-ambient (θ_{JA}) for the mountings shown is to be used as typical guideline values for preliminary engineering or in case the tie point temperature cannot be measured.

TYPICAL VALUES FOR θ_{JA} IN STILL AIR

MOUNTING METHOD	1/8	3/8	1/2	$R_{\theta JA}$
1	75	85	95	°C/W
2	85	95	105	°C/W
3		50		°C/W

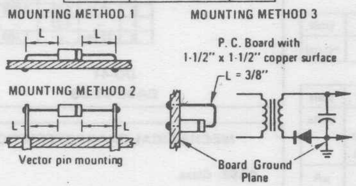
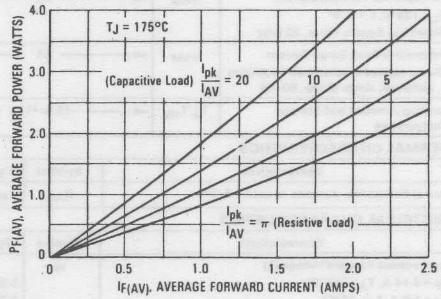


FIGURE 5 — FORWARD POWER DISSIPATION



MOTOROLA *Semiconductor Products Inc.*

BOX 20912 • PHOENIX, ARIZONA 85036 • A SUBSIDIARY OF MOTOROLA INC.

P.O. BOX 20912 • PHOENIX, ARIZONA 85036

PRODUCT PREVIEW DATA SHEET

SWITCHMODE POWER RECTIFIERS

... designed for use in switching power supplies, inverters and as free wheeling diodes, these state-of-the-art devices have the following features:

- Ultrafast 35 nanosecond recovery time
- 175°C operating junction temperature
- Popular TO-220 package

ULTRAFAST RECTIFIERS

8 AMPERES
50-150 VOLTS

CASE 2218-01
TO-220AC

This is advance information on a new introduction and specifications are subject to change without notice.

MAXIMUM RATINGS

Rating	Symbol	MUR805	MUR810	MUR815	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	150	Volts
Average Rectified Forward Current T_C 150°C (Rated V_R)	$I_{F(AV)}$	8	8	8	Amps
Peak Repetitive Forward Current (Rated V_R, Square Wave, 20 kHz) T_C=150°C	I_{FRM}	16	16	16	Amps
Nonrepetitive Peak Surge Current (Surge applied at rated load conditions halfwave, single phase, 60 Hz)	I_{FSM}	100	100	100	Amps
Operating Junction Temperature	T_J	-65 to +175	-65 to +175	-65 to +175	°C
Storage Temperature	T_{stg}	-65 to +175	-65 to +175	-65 to +175	°C

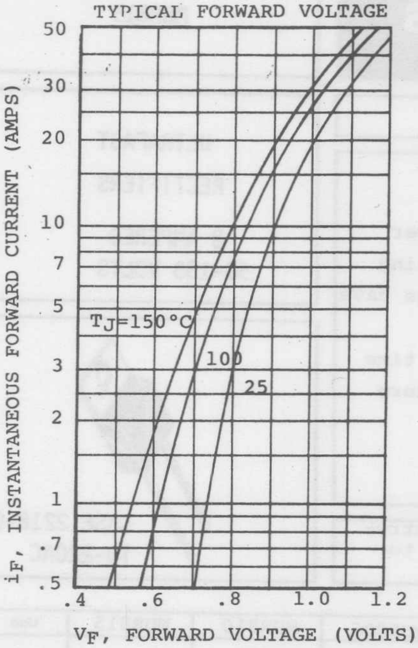
THERMAL CHARACTERISTICS

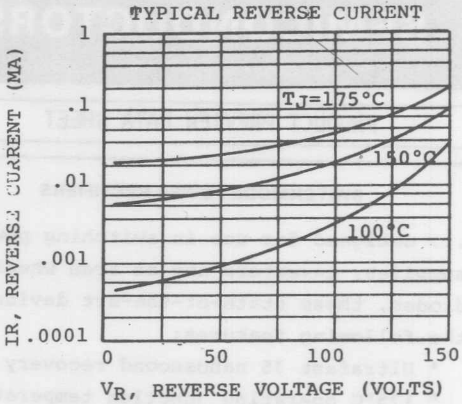
Characteristic	Symbol	MUR805	MUR810	MUR815	Unit
Maximum Thermal Resistance, Junction to Case	$R_{\theta JC}$	3.0	3.0	3.0	°C/W

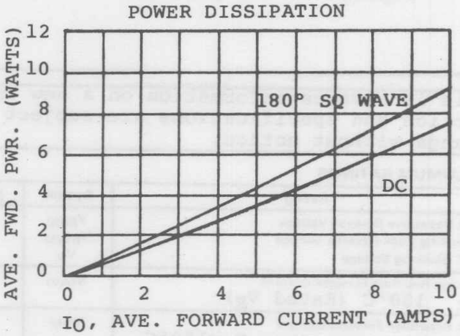
ELECTRICAL CHARACTERISTICS

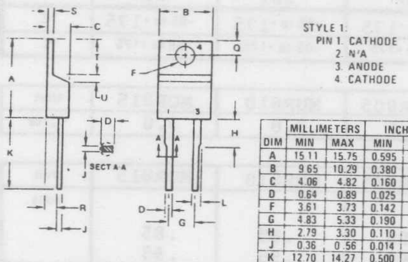
Characteristic	Symbol	MUR805	MUR810	MUR815	Unit
Maximum Instantaneous Forward Voltage (1) (i_F = 8 A, T_C = 150°C) (i_F = 8 A, T_C = 25°C)	v_F	.85 .95	.85 .95	.85 .95	Volts
Maximum Instantaneous Reverse Current (1) (Rated dc Voltage, T_C = 150°C) (Rated dc Voltage, T_C = 25°C)	i_R	250 5	250 5	250 5	UA
Maximum Reverse Recovery Time (I_F=1.0 Amp, di/dt=50A/usec)	t_{rr}	35	35	35	nsec

(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.



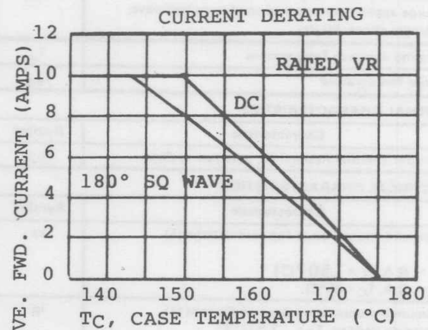






CASE 221B-01
TO-220AC

DIM	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	15.11	15.75	0.595	0.620
B	9.65	10.29	0.380	0.405
C	4.06	4.82	0.160	0.190
D	0.64	0.89	0.025	0.035
F	3.61	3.73	0.142	0.147
G	4.83	5.33	0.190	0.210
H	2.79	3.30	0.110	0.130
J	0.36	0.56	0.014	0.022
K	12.70	14.27	0.500	0.562
L	1.14	1.27	0.045	0.050
Q	2.54	3.04	0.100	0.120
R	2.04	2.79	0.080	0.110
S	1.14	1.39	0.045	0.055
T	5.97	6.48	0.235	0.255
U	0.76	1.27	0.030	0.050



MOTOROLA
SEMICONDUCTORS
P.O. BOX 20912 • PHOENIX, ARIZONA 85036

MUR1605CT
MUR1610CT
MUR1615CT

PRODUCT PREVIEW DATA SHEET

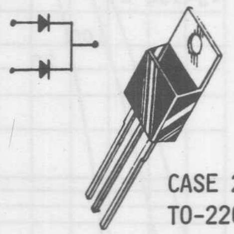
ULTRAFAST RECTIFIERS

16 AMPERES
50-150 VOLTS

SWITCHMODE POWER RECTIFIERS

... designed for use in switching power supplies, inverters and as free wheeling diodes, these state-of-the-art devices have the following features:

- Ultrafast 35 nanosecond recovery time
- 175°C operating junction temperature
- Popular TO-220 package



CASE 221A-02
TO-220AB

This is advance information on a new introduction and specifications are subject to change without notice.

MAXIMUM RATINGS

Rating	Symbol	MUR1605CT	MUR1610CT	MR1615CT	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	150	Volts
Average Rectified Forward Current Per Diode T_C = 150°C (Rated V_R, Total Device	$I_{F(AV)}$	8 16	8 16	8 16	Amps
Peak Repetitive Forward Current Per Diode Leg (Rated V_R, Square Wave, 20 kHz) T_C=150°C	I_{FRM}	16	16	16	Amps
Nonrepetitive Peak Surge Current (Surge applied at rated load conditions halfwave, single phase, 60 Hz)	I_{FSM}	100	100	100	Amps
Operating Junction Temperature	T_J	65 to +	-65 to +	-65 to +	°C
Storage Temperature	T_{stg}	-65 to +175	-65 to +175	-65 to +175	°C

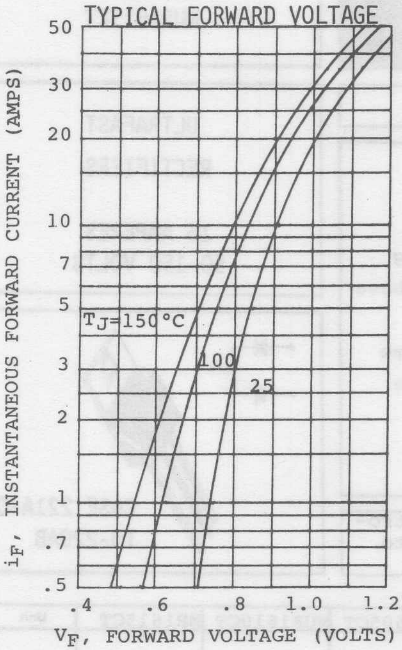
THERMAL CHARACTERISTICS Per Diode Leg

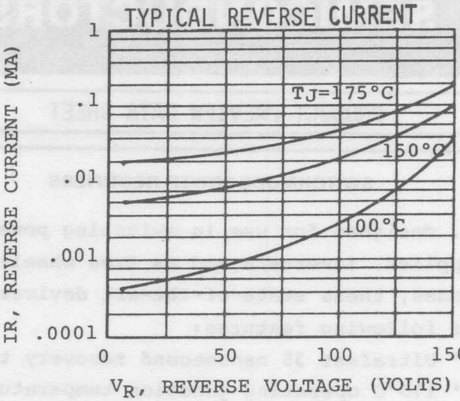
Characteristic	Symbol	MUR1605CT	MUR1610CT	MUR1615CT	Unit
Maximum Thermal Resistance, Junction to Case	$R_{\theta JC}$	3.0	3.0	3.0	°C/W

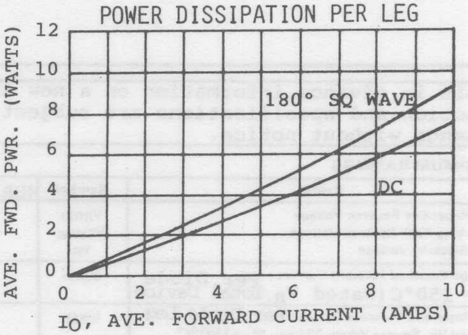
ELECTRICAL CHARACTERISTICS Per Diode Leg

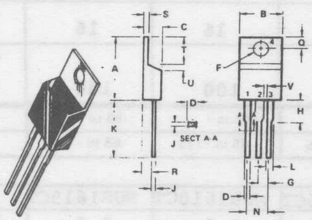
Characteristic	Symbol	MUR1605CT	MUR1610CT	MUR1615CT	Unit
Maximum Instantaneous Forward Voltage (1) (i_F = 8 A, T_C = 150°C) (i_F = 8 A, T_C = 25°C)	v_F	.85 .95	.85 .95	.85 .95	Volts
Maximum Instantaneous Reverse Current (1) (Rated dc Voltage, T_C = 150°C (Rated dc Voltage, T_C = 25°C)	i_R	250 5	250 5	250 5	UA
Maximum Reverse Recovery Time (I_F=1.0 Amp, di/dt=50A/usec)	t_{rr}	35	35	35	nsec

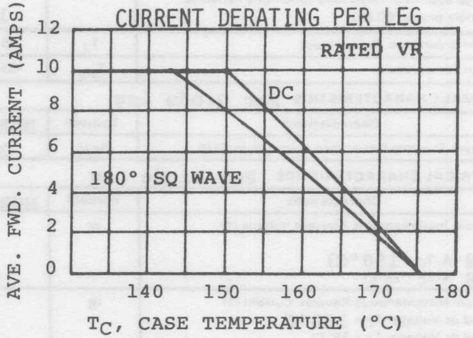
MUR1605CT, MUR1610CT, MUR1615CT











PIN 1. ANODE 1
2. CATHODE
3. ANODE 2
4. CATHODE

CASE 221A-02
TO-220AB

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	15.11	15.75	0.595	0.620
B	9.65	10.29	0.380	0.405
C	4.06	4.82	0.160	0.190
D	0.64	0.89	0.025	0.035
F	3.61	3.73	0.142	0.147
G	2.41	2.67	0.095	0.105
H	2.79	3.30	0.110	0.130
J	0.36	0.56	0.014	0.022
K	12.70	14.27	0.500	0.562
L	1.14	1.27	0.045	0.050
N	4.83	5.33	0.190	0.210
Q	2.54	3.04	0.100	0.120
R	2.04	2.79	0.080	0.110
S	1.14	1.39	0.045	0.055
T	5.97	6.48	0.235	0.255
U	0.76	1.27	0.030	0.050
V	1.14		0.045	

SCHOTTKY RECTIFIERS

I_o	I_o AVERAGE RECTIFIED FORWARD CURRENT (AMPERES)											
	1		3		3	5	8	15		25		
CASE	59-04 PLASTIC 		267 PLASTIC 		60 METAL TIN-CAN 			56-02 DO-4 METAL 				
V_{RRM} (VOLTS)												
20	1N5817	MBR120P	1N5820	MBR320P	MBR320M	1N5823	BYS08-20	1N5826	MBR1520	1N5829	MBR2520	
30	1N5818	MBR130P	1N5821	MBR330P	MBR330M	1N5824	BYS08-30	1N5827	MBR1530	1N5830	MBR2530	1N6095
35					MBR335M				MBR1535		MBR2535	
40	1N5819	MBR140P	1N5822	MBR340P	MBR340M	1N5825	BYS08-40	1N5828	MBR1540	1N5831	MBR2540	1N6096
45							BYS08-45					
50							BYS08-50					
IFSM (A)	25	25	80	80	500	500	500	500	500	800	500	800
TL OR TC AT RATED I_o (°C)	90	80	95	85	90	80	100	80	80	85	80	70
TJ MAX	125	125	125	125	125	125	150	125	125	125	125	125
BARRIER METAL	CHROME						PLATINUM	CHROME				PLATINUM
VF MAX AT I_o (V)	0.60	0.65	0.53	0.60	0.45	0.38	0.50	0.50	0.55	0.48	0.55	0.58

SCHOTTKY RECTIFIERS

Io	Io AVERAGE RECTIFIED FORWARD CURRENT (AMPERES)											
	30	30	35		40		40	50	60		75	
CASE	54 TO-3 METAL		56-02 DO-4 METAL		257 DO-5 METAL		43-02 PRESSFIT		257 DO-5 METAL			
												
V_{RRM} (VOLTS)												
20	MBR3020CT	...	MBR3520	BYS35-20	1N5832	MBR4020	MBR4020PF		MBR6020	BYS60-20	BYS75-20	MBR7520
30				BYS35-30	1N5833	MBR4030	MBR4030PF	1N6097		BYS60-30	BYS75-30	MBR7530
35	MBR3035CT		MBR3535			MBR4035			MBR6035			MBR7535
40					1N5834	MBR4040	MBR4040PF	1N6098				MBR7540
45	MBR3045CT SD241	SD41	MBR3545	BYS35-45					MBR6045 SD51	BYS60-45	BYS75-45	MBR7545
50				BYS35-50						BYS60-50	BYS75-50	
IFSM (A)	400	600	600	600	800	800	800	800	800	800	1000	1000
TL OR TC AT RATED Io (°C)	95		90	100	75	70	50	70	90	100	100	90
TJ MAX	150	150	150	150	125	125	125	125	150	150	150	150
BARRIER METAL	PLATINUM				CHROME				PLATINUM			
VF MAX AT Io (V)	0.65	0.55	0.55	0.60	0.59	0.63	0.63	0.65	0.65	0.68	0.64	0.62

TO220 RANGE

	I_o AVERAGE RECTIFIED FORWARD CURRENT (AMPERES)					
	7	10	16	15	20	30
V_{RRM} (Volts)	TO220AC 	TO220AC 	TO220AC 	TO220AB 	TO220AB 	TO220AB 
20		MBR1020		MBR1520CT		
30						
35	MBR735	MBR1035	MBR1635	MBR1535CT	MBR2035CT	MBR2535CT
40						
45	MBR745	MBR1045	MBR1645	MBR1545CT	MBR2045CT	MBR2545CT
I_{FSM} (Amps)	150	150	150	150	150	150
Tc RATED I_o (°C)	105	135		105	135	105
Tj (MAX) (°C)	150	150	150	150	150	150
MAX VF IFM = I_o	0,57	0,57	0,57	0,57	0,57	0,57